(Tel-Aviv University) found a strong sensitivity of the limiting stroke to the exit velocity profile and a lack of sensitivity of ring circulation to both the exit profile and piston motion. The model reproduces these facts as well. Finally, using an inverse design procedure, piston histories were found that may overcome the limit at a stroke-to-diameter ratio of 4 and thereby lead to larger coherent masses.

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B-Spline Method for Turbulent Flow Simulation

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B-splines are an attractive basis for a numerical method. Because of the continuity of a high number of derivatives, B-splines have resolving power approaching that of spectral functions, but provide greater flexibility in geometry and grid distribution. They are not as flexible as finite elements, but they are much more accurate for the same number of degrees of freedom. Furthermore, if they are used in a Galerkin formulation, the resulting scheme conserves not only the discretized quantities (such as mass and momentum) but quadratic invariants as well (such as kinetic energy for inviscid incompressible flow). This protects the scheme against aliasing and ensures that there is no numerical smoothing of the unresolved scales of motion.

The B-spline method was implemented for incompressible flow in two generalized coordinates using a Galerkin formulation. Fourier expansions are used for the third direction. The B-spline zonal mesh capability developed by Shariff and Moser (1995), which gives the same high degree of derivative continuity at zonal boundaries as everywhere else, is used. It increases gridding flexibility and leads to a significant reduction in the number of grid points required. Basis vectors are used that already satisfy the incompressibility constraint. This leads to a reduction in the number of degrees of freedom from four to two per grid point. However, there is a high cost associated with calculating the Galerkin nonlinear term and in inverting the mass matrix. More work is required to improve the efficiency of the method.

In the figure, the experimental (symbols) and computed (lines) frequency spectra in the wake of a turbulent flow past a circular cylinder at a Reynolds number of 3900 are compared. The computations are
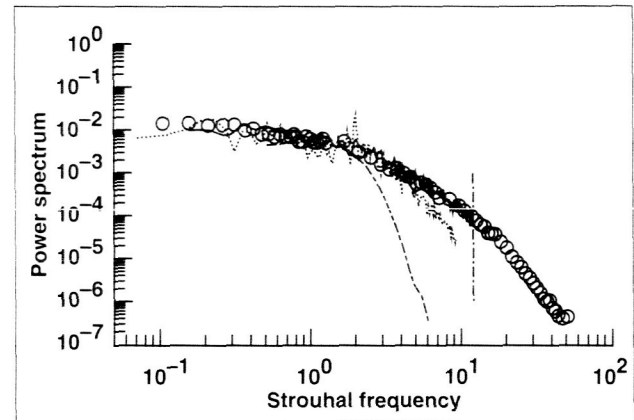

Fig. 1. Frequency spectrum of velocity fluctuations in the wake of a circular cylinder showing the resolving power of various schemes.

all large-eddy simulations with the dynamic model. The curves show the result of three different numerical methods. The B-spline method (solid line) with quadratic basis functions gives excellent accuracy up to the smallest scale it resolves (shown by the chain-dotted vertical line). The energy-conserving second-order finite-difference scheme (dashed) is accurate for a smaller range of frequencies, whereas the fifth-order upwind biased scheme (chain-dashed) is much too dissipative for a large range of scales.

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